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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 :		(11) International Publication Number:
F16C 7/02	A1	WO 86/ 04122
		(43) International Publication Date: 17 July 1986 (17.07.86)

(21) International Application Number: PCT/GB86/00013

(22) International Filing Date: 9 January 1986 (09.01.86)

(31) Priority Application Number: 8500684

(32) Priority Date: 11 January 1985 (11.01.85)

(33) Priority Country: GB

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(81) Designated States: AT (European patent), AU, BE (European patent), BR, CH (European patent), DE (European patent), DK, FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), US..

Published
With international search report.

(54) Title: CONNECTING ROD

(57) Abstract

A connecting rod is divided lengthwise along a surface (1) into 2 mating parts (2, 3) and is formed from fibre reinforced plastics material with the majority of the reinforcing fibres extending substantially along the length of the connecting rod. Steps (18, 19) in the mating surfaces of the parts (2, 3) cooperate to provide transverse lands which bear one upon the other to resist shear forces along the surface (1).

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Title: Connecting Rod

The invention concerns connecting rods, especially of fibre reinforced plastics (FRP) material, which can replace conventional metal connecting rods in reciprocating piston and cylinder machines, such as internal combustion engines or refrigeration compressors, for example.

Much design effort has been directed with the object of reducing the rotating mass in internal combustion engines. As well as the direct effect of reducing the mass of any particular component, there are also likely to be consequential benefits. A reduction in connecting rod mass leads to reduced inertia forces so that bearing sizes can be reduced, and the lubrication system simplified. The crank mass can be reduced, along with other associated engine parts. Vibration and noise are also reduced.

FRP is thus an attractive proposition as material for engine components, including connecting rods, and has received much consideration with this in mind. However, use of FRP as a connecting rod material presents a number of difficulties, especially in relation to an existing engine in which the design of other components is not to be changed.

A principal difficulty arises from the need to assemble the connecting rod to the crankshaft. This is conventionally done by forming the lower half of the big end bearing housing as a separate part. The upper half of the big end housing is formed integrally with the remainder of the connecting rod, and the two halves are provided with flanges on each side, by means of which the two halves of the housing are bolted together after assembly to the connecting rod.

This approach is inappropriate for an FRP connecting rod. The bolts are required to transmit the loading in the principal axial direction of the connecting rod, and thus very substantial masses of FRP would be required to withstand the high stresses in the flange areas, and thus relatively long steel bolts would be required to secure them together. This large FRP mass, as well as the extra mass of the longer bolts substantially detracts from the principal advantage sought, namely a reduction of reciprocating and rotating mass. Also the extra space envelope required by the built up flange

areas would be a great disadvantage, and probably could not be accommodated in an existing engine designed originally for conveniional steel connecting rods.

A further point arises from the fact that the majority of the reinforcing fibres would need to be unidirectionally alligned along the longitudinal axis of the connecting rod. This means that the bolts might tend to pull through the flange areas, because of a lack of shear resistance by the predominantly unidirectional fibres.

It is therefore more suitable for a connecting rod made from fibre reinforced plastics material to be divided along its length in such a way as to devide the big end bearing into 2 parts which can be assembled to a crankshaft bearing. Such a construction has been described in UK Patent A 477342 where a metal crankshaft is formed from 2 parts separated along the longitudinal axis of the crankshaft, the parts being bolted together, and in UK Patent A 1349 691 which describes a crankshaft similar to that of UK A 477342 but in which each part is formed from a plurality of steel sheet strips.

However, the axial loading on a connecting rod is not symmetrical, as a result of various factors such as the inclination of the rod with respect to the piston axis, inertia forces resulting from the connecting rod's own mass, and asymmetric hydrodynamic bearing loads. In redistributing the asymmetric axial loads as between the 2 longitudinally divided parts of the rod, substantial shear forces are set up along the mating surfaces of the 2 parts. Fibre reinforced plastic connecting rods do not resist such forces as efficiently as do metal connecting rods.

According to the present invention, a connecting rod for a reciprocating piston and cylinder machine, has the connecting rod formed of fibre reinforced plastics material and divided along its length in such a way as to divide the big end bearing into 2 parts which can be assembled to a crankshaft bearing, and is characterised in that each part has at least one step which conforms to a step in the other part so as to provide transverse lands which bear one upon the other to resist shear forces set

up along the length of mating surfaces of the 2 parts of the connecting rod.

Preferably the reinforcing fibres extend substantially along the length of the connecting rod.

Steps facing in both axial directions may be provided on each mating face so as to resist shear forces acting in both directions.

Suitable plastics materials for use as the matrix material of the connecting rod include epoxy resins, polyester resins, phenolic resins, vinyl esters, polyamides and polyimides.

The 2 parts of the connecting rod may be secured together by means of one or more screw threaded connecting means.

Alternatively or additionally each of the mating surfaces may be provided with a keyway, the keyways being adjacent one another on assembly, and being adapted to receive a key which, alone or in conjunction with other fixing devices, locks together the two parts.

The invention will now be further described by way of example only with reference to the accompanying drawings, of which

Figure 1 shows in end elevation a connecting rod in accordance with the invention,

Figures 1A to 1D are sections on the line A - B of Figure 1 showing various possible transverse cross-sections for the connecting rod,

Figures 1E and 1F are detail views showing alternative methods of fixing together the two parts of the connecting rod of Figure 1

Figure 2 is an end sectional elevation on the line AA of the connecting rod shown in Figure 1,

Figures 2A and 2B are detail views showing alternative methods of fixing together the two parts of the connecting rod of Figures 1 and 2,

Figure 3 shows another embodiment of connecting rod in accordance with the invention,

Figures 3A and 3B are detail views showing alternative methods of fixing together the two parts of the connecting rod of Figure 3,

Figure 4 shows another embodiment of connecting rod in accordance with the invention,

Figure 4A is a detail view to an enlarged scale showing the method of fixing together the two parts of the connecting rod of Figure 4,

Figure 5 shows another embodiment of connecting rod in accordance with the invention,

Figure 6 shows another embodiment of connecting rod in accordance with the invention, assembled with a piston,

Figure 7 is a perspective view of the connecting rod of Figure 6, and

Figure 8 is a perspective view of a section of one part of the connecting rod of Figures 6 and 7.

As shown in Figures 1 and 2, a connecting rod is divided lengthwise along the surface 1 into two mating parts 2, 3. Each of the

parts 2, 3 is formed of glass fibre reinforced epoxy resin. The part 2 includes a housing for the gudgeon pin bearing 4, and the reinforcing fibres therein are oriented generally longitudinally of the connecting rod, although in the gudgeon pin area they are oriented so as to pass around the bearing. The bearing 4 is tapered externally, and is adhesively bonded in place. The part 3 is thus not as long as the part 2, and the reinforcing fibres therein are also aligned generally longitudinally. Although the reinforcing fibres in the parts 2, 3 are generally unidirectional, and longitudinally aligned, they may advantageously follow the bearing contour in the region of the big end half-bearings 5, and a proportion of angled fibres may be included to resist delamination and to provide strength in directions other than the principal (longitudinal) stress direction. The half-bearings 5 are provided with lugs 5A to prevent their rotation within their housing in the connecting rod.

The two parts 2, 3 are fixed together below the big end bearing by a transverse screw 6. The screw is received in a threaded bore of a cross-dowel 7 which is moulded into the part 3. Just below the gudgeon pin bearing the parts 2, 3 are similarly fixed by an inclined transverse screw 8 and a moulded-in steel cross-dowel 9. A further fixing may be provided if necessary in the mid-region of the connecting rod, mainly to resist the large hydrodynamic bearing forces which may tend to separate the two parts in this region. This fixing can be a simple nut and bolt fixing as shown at 10, in this instance acting on the central webs 11 of a waist cross-section as shown in Figure 1A. An alternative possible fixing method is shown in Figure 1E, which is a detail sectional view showing the web sections 11 of the two parts 2, 3 joined together by means of a key 12 of parallelogram cross-section. Each of the parts 2, 3 is provided with a respective projection 13 extending across the dividing surface 1, and a recess 14 into which the corresponding projection on the other part can be received. Each projection 13 has a transverse step 15 which co-operates with the corresponding recess to limit relative movement of the parts 2, 3 in the longitudinal direction of the surface 1. Each projection also has an inclined step 16, and when assembled a space is defined between the steps 16 into which the key 12 is received as a close sliding fit. The key thus prevents

separation of the parts 2, 3.

In the alternative fixing shown in Figure 1F, the webs 11 of the parts 2, 3 are held together by a spring clip 17 by which the webs are embraced.

Alternative possible cross-sections on the line BB are shown in Figures 1B, 1C and 1D, for which other appropriate fixing methods may be used if necessary.

In use the connecting rod is subjected to stresses acting principally in the longitudinal direction, ie along a line linking the big and small end bearings 4, 5. There will also be some appreciable bending moment acting perpendicular to the plane of the surface 1, owing largely to inertia of the rod itself. In addition, there will be substantial shear forces tending to separate the two parts 2, 3 in the longitudinal direction of the surface 1. These shear forces arise largely from the principal longitudinal stresses, as well as from inertia of the connecting rod, and result from the inclination of the connecting rod with respect to the piston/cylinder axis.

A very important feature of the invention is the provision of shear lands which resist separation of the parts 2, 3 under the action of such shear forces. In this embodiment the shear lands are provided by steps in the respective mating surfaces 1 which conform one to the other and bear on one another to resist these shear forces. In Figure 1, these steps are indicated at 18 and 19, and the larger step 20 in this case also constitutes a very effective shear land. The steps 19 and 20 resist shear forces generated by the power stroke. The step 18 resists shear forces resulting from inertia of the connecting rod during the return stroke and may not always be necessary.

By means of these lands, the longitudinal stresses in the connecting rod are efficiently redistributed throughout the structure of the rod .

In figure 3 there is shown a connecting rod formed in two parts 31, 32 which are divided along the longitudinal surface 33. The rod includes a small end bearing 34, and a big end bearing 35 provided with projections 36 to prevent its rotation within its housing in the rod. The connecting rod is made of carbon fibre-reinforced epoxy

resin, the fibres being aligned longitudinally as indicated at 37 in the mid-region, which includes stiffening webs 38. The two parts 31, 32 are provided with overlapping lugs 39, 40 respectively above the small end and below the big end, and the two halves are held together by pins 41, 42 which pass through holes in the lugs.

As in the case of the embodiment described with reference to Figures 1 and 2, the connecting rod will be subjected in use, inter alia, to shear forces tending to separate the two parts 31, 32 by shearing along the longitudinal surface 33. In the case of the present embodiment (Figure 3), there are provided shear lands in the form of steps 43, 44, 45 and 46 in the two surfaces which mate along the line 33. Corresponding steps in the two parts 31, 32 conform closely to each other and bear on one another to resist these shear forces.

In Figure 4 there is shown a connecting rod of glass-fibre reinforced epoxy resin, comprising two halves 50, 51 divided along a generally longitudinal plane 52. Transverse stiffening webs are provided at 53, and shear lands are provided at 54, 55 to resist longitudinal shear forces tending to separate the parts 50, 51 along the line 52. In addition, further shear lands are provided on the part 50 by a pair of opposed inclined steps 56, 57 which define the boundaries of a divergent tongue 58, which is loosely received in a corresponding divergent recess in the part 51. The looseness if fully taken up by a C-shaped locking member 59 of rectangular cross-section, which slides transversely into the upper and lower spaces formed between the tongue 58 and its corresponding recess. The locking member 59 embraces the tongue 58 as illustrated in Figure 4A, and locks the two parts 50, 51 together, at the same time serving to transfer the loads across the shear lands at 56 and 57. The need for fixing bolts to join the parts 50, 51 is eliminated.

In Figure 5 there is shown another embodiment of split connecting rod in accordance with the invention. The rod is divided longitudinally along the line 63 into two parts 60, 61, but in this case the two parts are integrally formed in that they are joined at the outer extemity of the small end 62. Shear lands 64, 65 are provided to resist shear forces tending to separate the two parts by longitudinal shear. An aperture 66 is left in the mid-region of the rod for

weight saving, while webs 67 provide reinforcement at the inner extremity of the housing for the big end bearing shells 68. The flanged bearing shells 68 are provided with projections 69 to prevent their rotation in the housing.

The two parts 60, 61 are secured together by a pair of transverse machine screws 70, one inward of the small end and the other outward of the big end. Each screw 70 is received within an internally screw-threaded metal insert 71 moulded into the connecting rod material.

The two parts 60, 61 are integrally moulded from fibre-reinforced epoxy resin material, the fibres and matrix material being continuous around the outer extremity of the small end 62.

A particularly light and strong structure is thus formed.

For assembly and removal of the bearing shells, and for assembly to the crankshaft, the screws 70 are removed and the parts 60, 61 can be separated as indicated in outline at 72 by using flexibility of the material.

In Figure 6 there is shown a further embodiment of connecting rod in accordance with the invention comprising two parts 80, 81. In this embodiment, a conventional gudgeon pin is replaced by a pair of hemispherical projections 82, 83. These are moulded one on each of the two parts, and act as bearings on which a piston 88 can rotate relative to the connecting rod. As shown more clearly in Figures 7 and 8, the upper part of the connecting rod (which includes the projections 82, 83) is divided longitudinally in the plane of rotation thereof, as indicated at 84, while the lower part (which includes the big end 85) is divided longitudinally in a plane at right angles thereto, indicated at 85. The transition between planes 84 and 85 is by way of mating steps on the two parts at 86 and 87, which constitutes shear lands As in the case of other embodiments, the shear lands are effective to resist shear stresses tending to separate the two parts along the longitudinal dividing planes 84, 85.

The two parts 80, 81 are each chamfered at 92 on the faces opposite to the projections 82, 83 to facilitate assembly to the piston 88 (Fig 6), and disassembly. In the assembled position, as well as by their interlocking geometry, the two parts 80, 81 are secured together by means, for example, of a transverse bolt 89

(Fig 6), and/or a diagonal set screw 90 passing across the shear level 86 (Fig 7), and/or by means of lugs 91 below the big end (Fig 7). The projections 82, 83 are received in part-spherical bearing recesses 95,96 in the piston 88.

In order to separate the parts 81 from each other and from the piston 88, the securing bolts, screws, etc are removed, and the two parts 80, 81 are first separated at the big end as indicated by the arrows 93 (Fig 7), the parts pivoting in the piston about the projections 82, 83. The connecting rod is thus freed from the crankshaft, and the interlocking geometry of the shear lands 86, 87 is separated. The two parts 80, 81 are then moved apart, eg so that the part 81 occupies the position indicated in chain lines 94 (Fig 6). The chamfers 92 permit the two parts 80, 81 to move together at the small end, and the projections 82, 83 are thus freed from the recesses 95, 96 permitting complete withdrawal and disassembly of the connecting rod.

Reassembly is achieved by reversing these steps.

Claims

What is claimed is:

1. A connecting rod for a reciprocating piston and cylinder machine, the connecting rod being formed of fibre reinforced plastics material and being divided along its length in such a way as to divide the big end bearing into 2 parts which can be assembled to a crankshaft bearing, characterised in that each part has at least one step which conforms to a step in the other part so as to provide transverse lands which bear one upon the other to resist shear forces set up along the length of mating surface of the 2 parts of the connecting rod.

2. A connecting rod according to Claim 1 characterised in that a major proportion of the reinforcing fibres are aligned substantially unidirectionally along the length of the connecting rod.

3. A connecting rod according to claim 1,2,characterised in that steps facing in both axial directions are provided on each part so as to resist shear forces acting in both directions.

4. A connecting rod according to any one preceding claim characterised in that the plastics matrix material of the connecting rod is selected from the group comprising epoxy resins, polyester resins, phenolic resins, vinyl esters, polyamides and polyimides.

5. A connecting rod according to any one preceding claim characterised in that the 2 parts of the connecting rod are secured together by means of one or more screw threaded connecting means.

6. A connecting rod according to any one preceding claim characterised in that the 2 parts of the connecting rod are provided with interlocking geometric forms by which they are secured together.

7. A connecting rod according to claim 6 characterised in that each of the 2 mating surfaces is provided with a keyway, the keyways being adjacent one another on assembly, and being adapted to receive a key which, alone or in conjunction with other fixing devices, locks together the 2 parts.

Fig. 1.

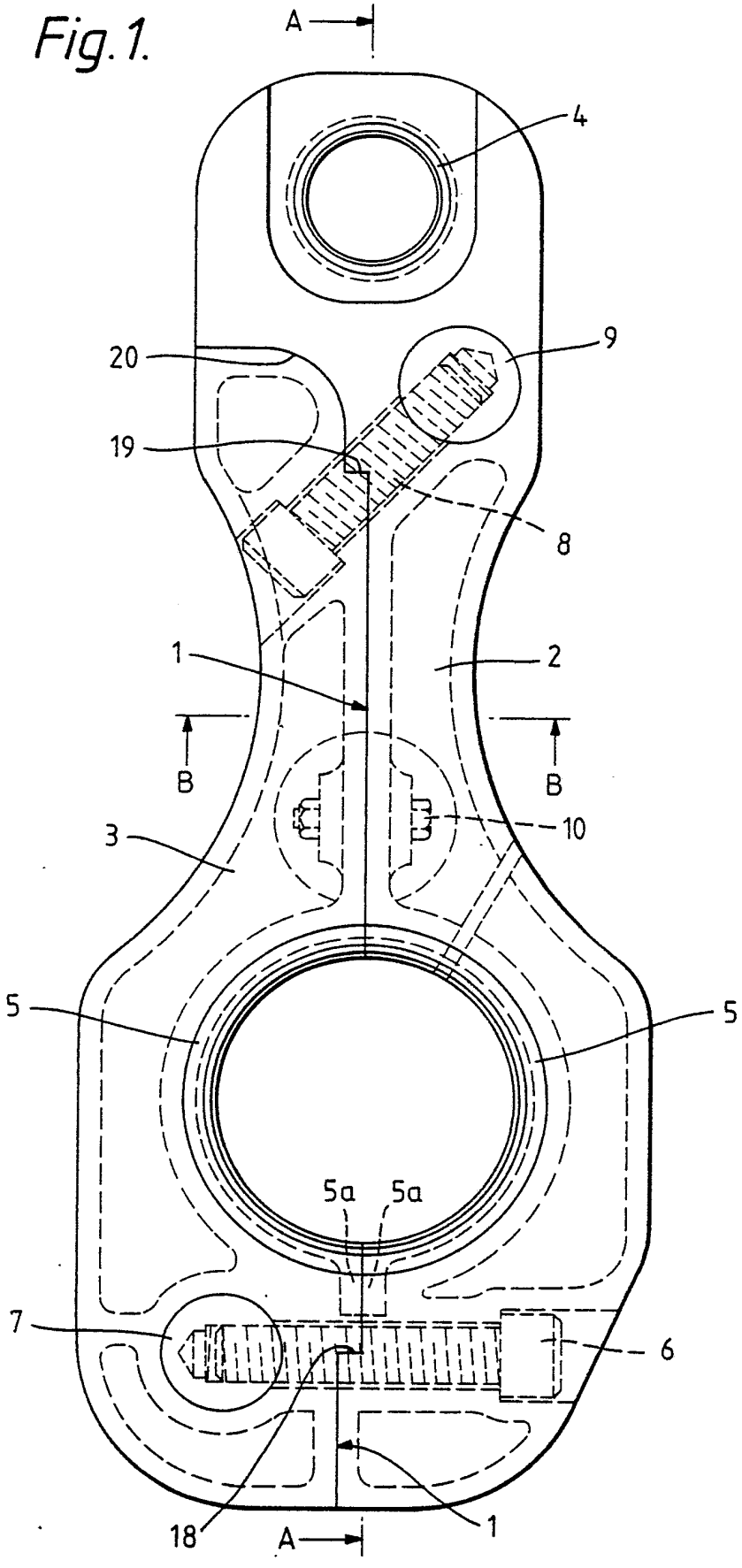


Fig.1A.

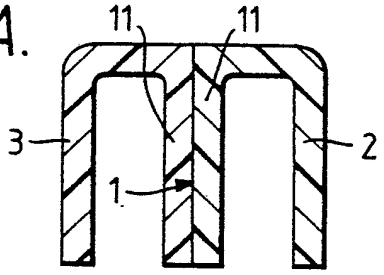


Fig.1B.

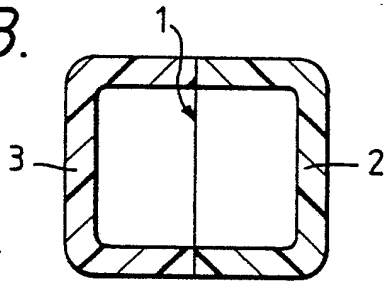


Fig.1C.

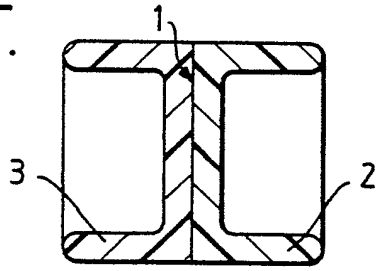


Fig.1D.

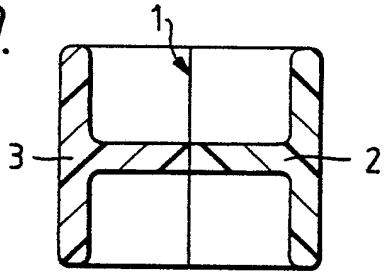


Fig.1E.

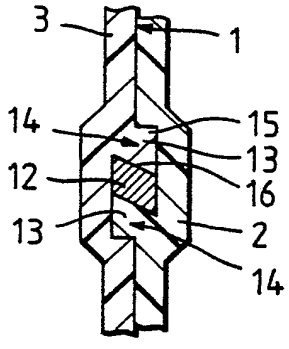


Fig.1F.

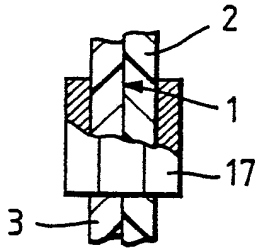


Fig.2.

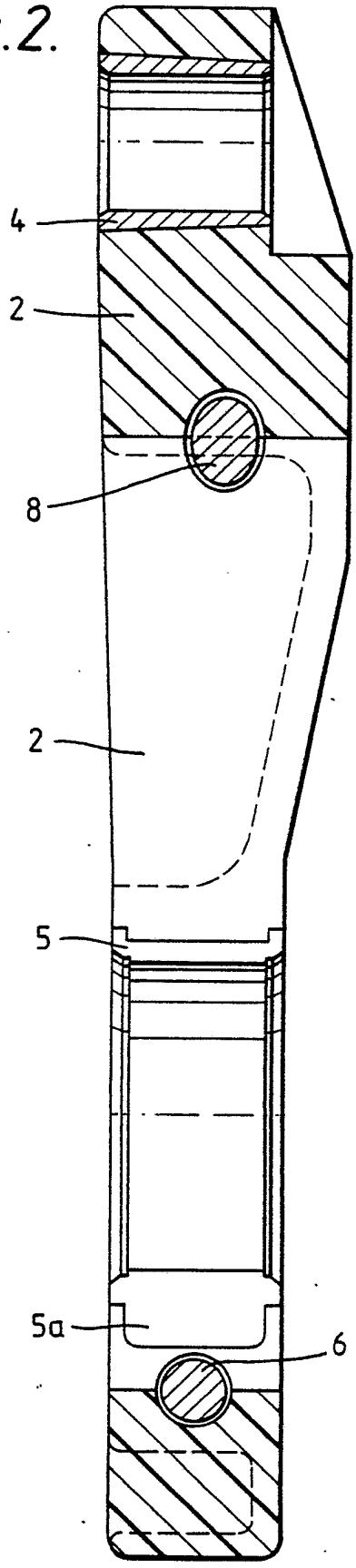


Fig. 3.

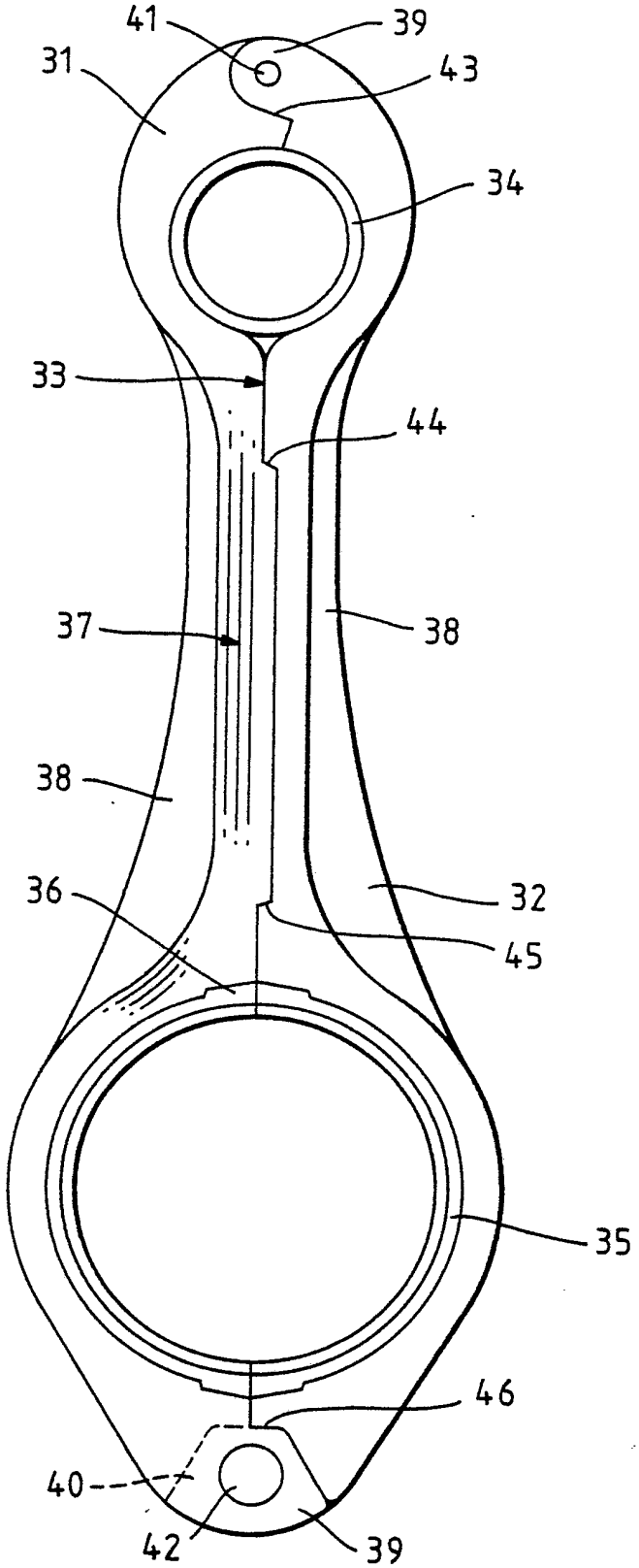


Fig.4.

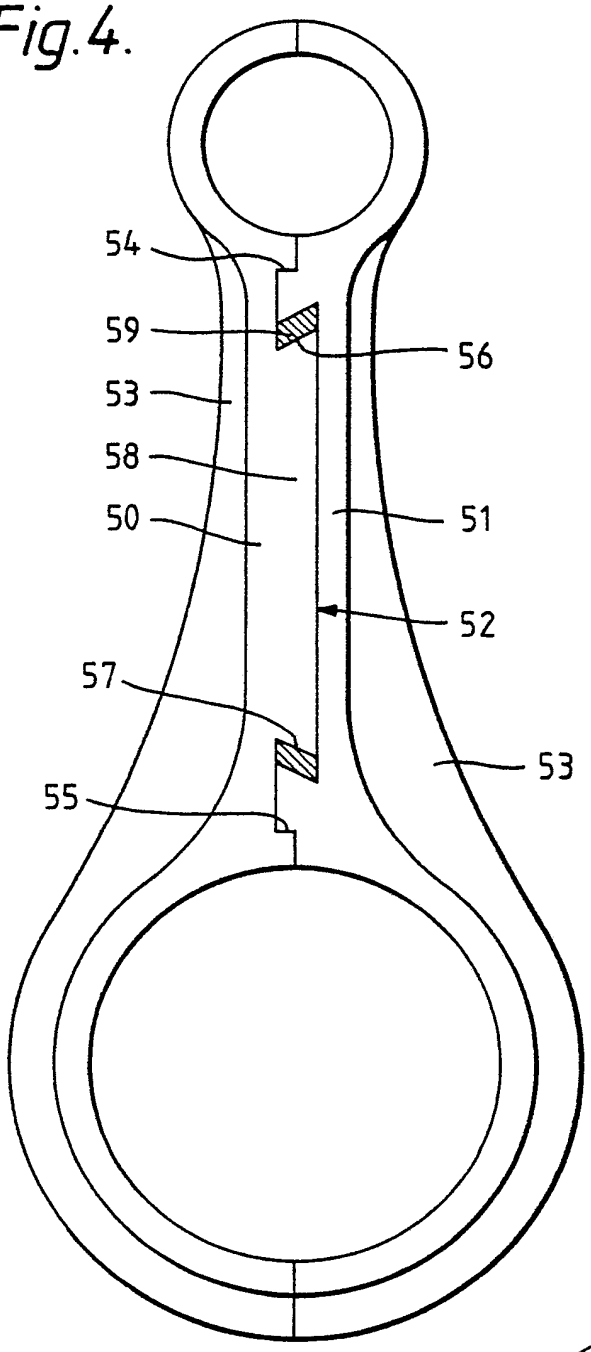


Fig.4A.

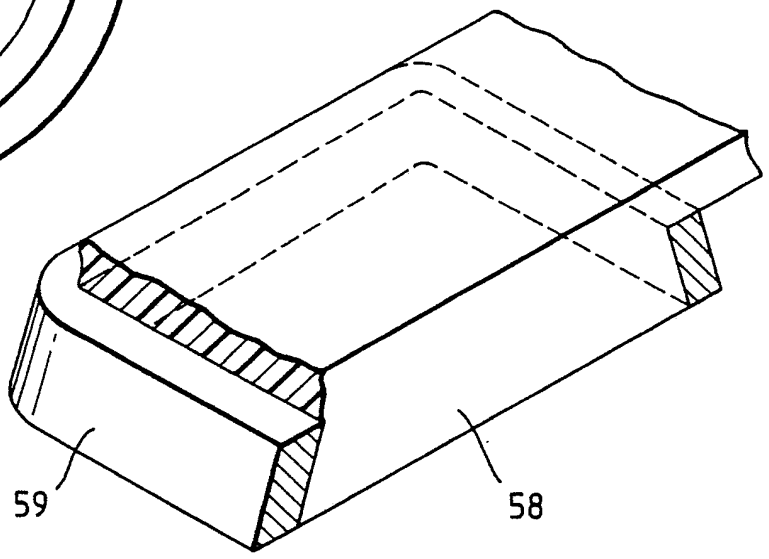


Fig. 5.

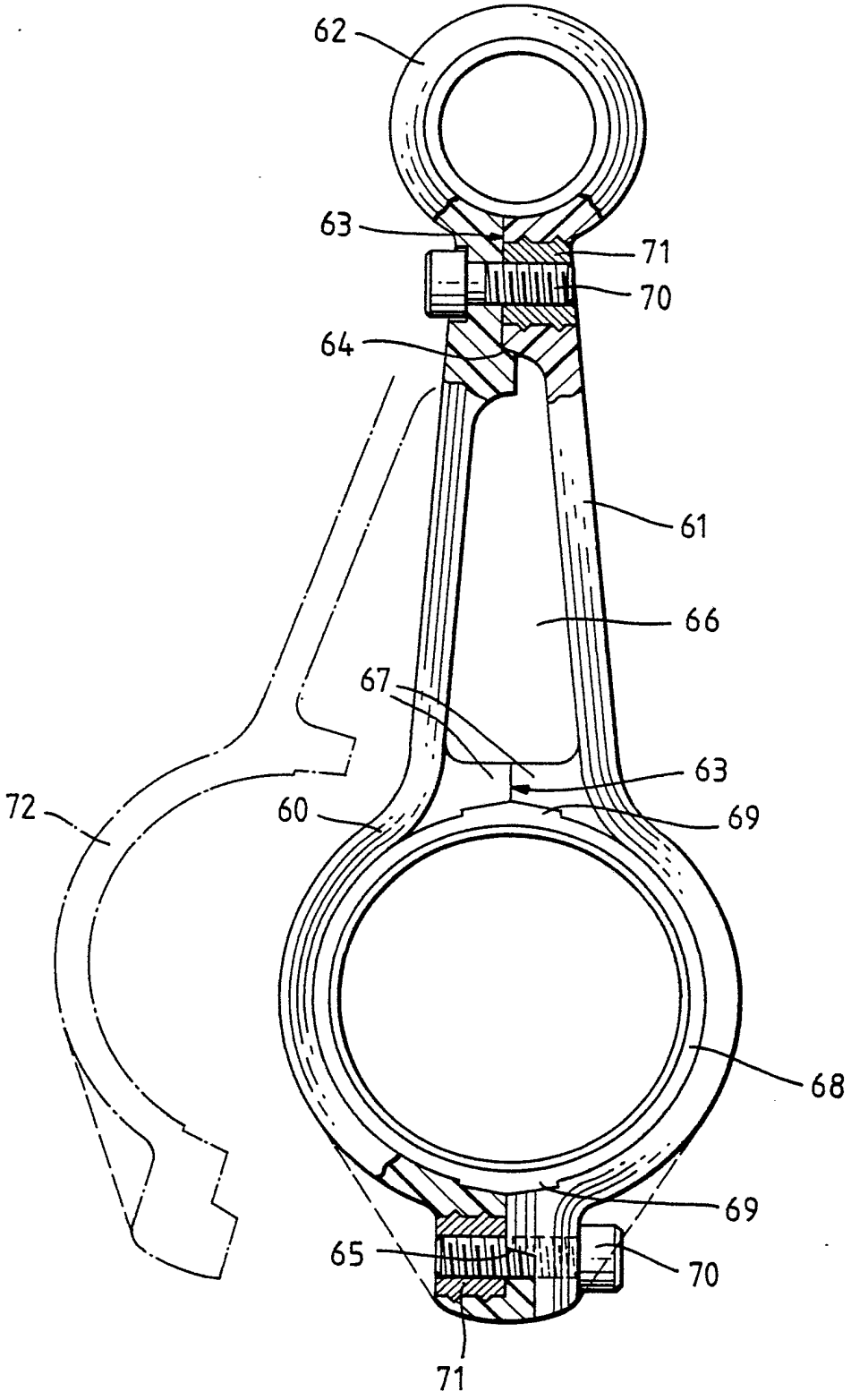


Fig.6.

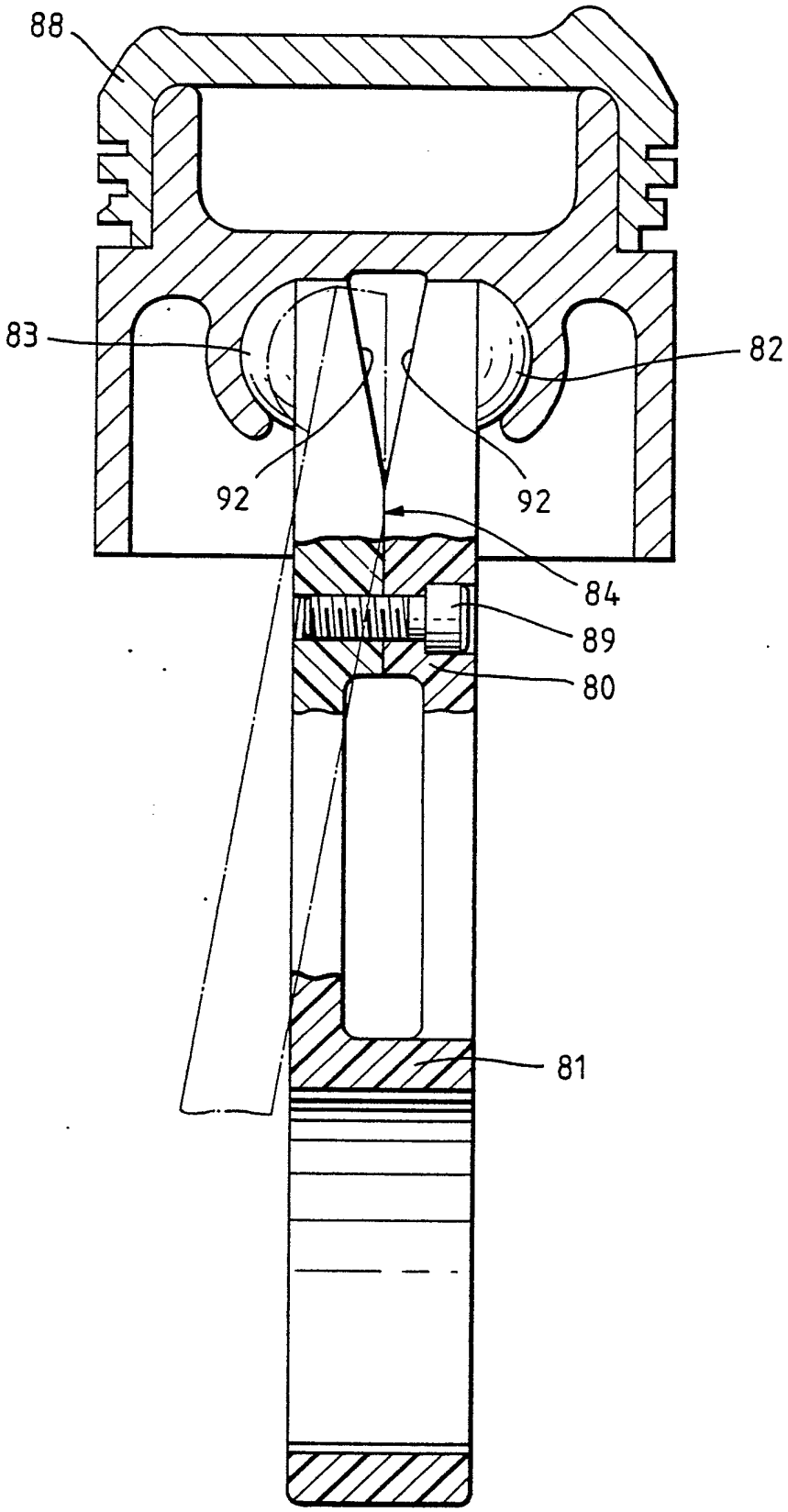


Fig.7.

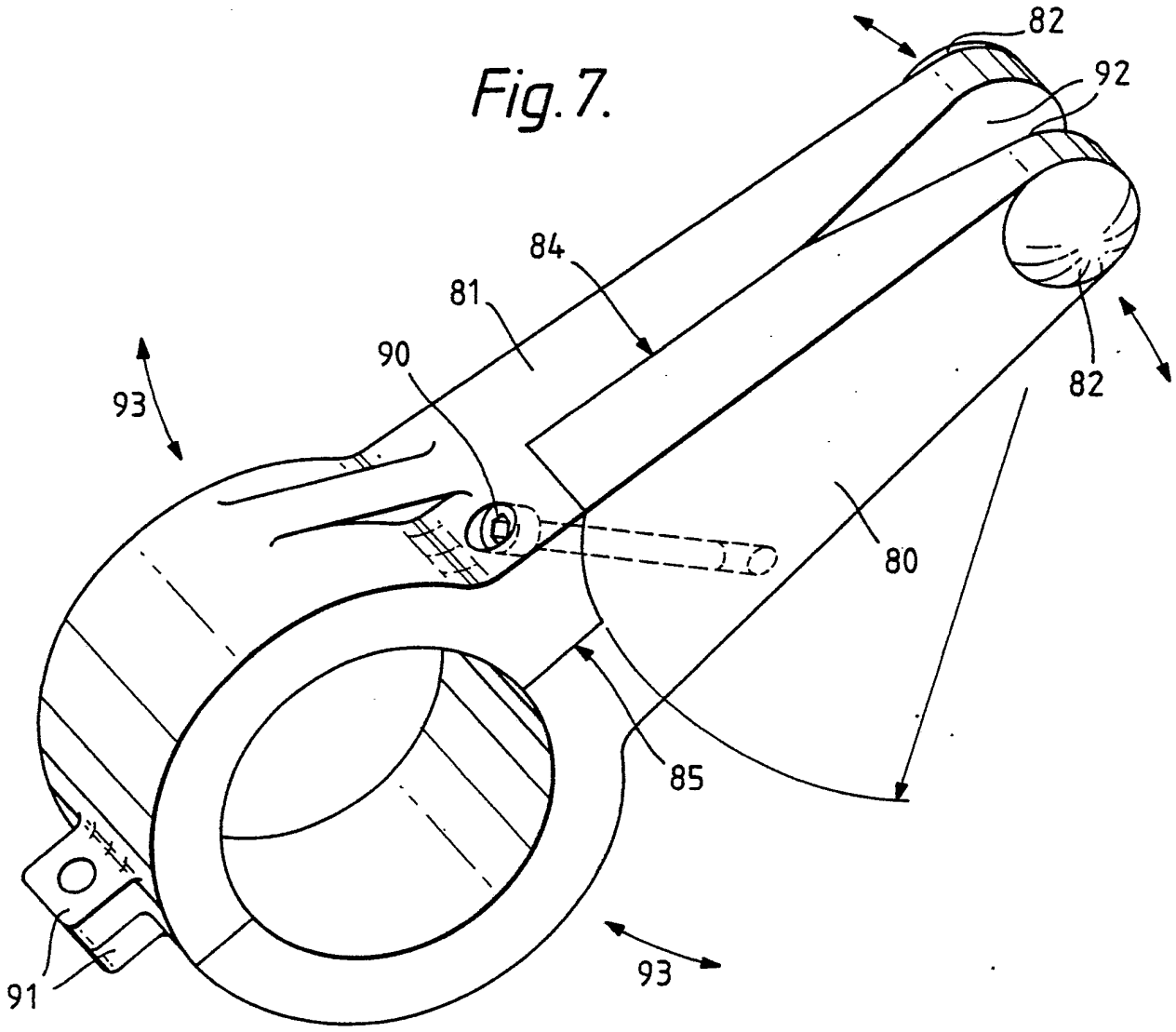
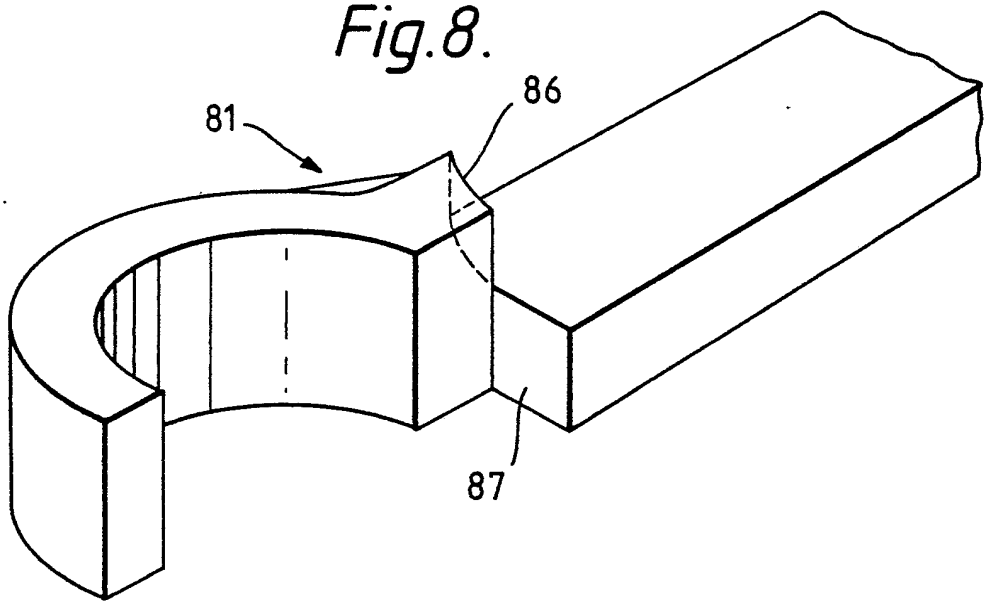


Fig.8.



INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 86/00013

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[4]: F 16 C 7/02

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC[4]	F 16 C

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	FR, A, 718435 (V. RAFAILOFF) 25 January 1932 --	
A	DE, C, 692385 (G. JAKUTEK) 23 May 1940 ------	

* Special categories of cited documents: [10]

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
2nd April 1986	16 AVR. 1986
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	M. VAN MOL

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/GB 86/00013 (SA 11782)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 09/04/86

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR-A- 718435		None	
DE-C- 692385		None	